

The SRTM Topographic Mapping Processor

Scott Hensley, Paul Rosen and Eric Gurrola

Jet Propulsion Laboratory
MS 300-235
4800 Oak Grove Drive
Pasadena, California 91109

(818)-354-3322/(818)-393-3077/sh@kaitak.jpl.nasa.gov

INTRODUCTION

In February 2000 the Shuttle Radar Topography Mission (SRTM) carried out a mission to map the world's landmass between $\pm 60^\circ$ using radar interferometry* [1]. The radar mapping instrument consisted of modified versions of the SIR-C C-band and X-band radars flown on the shuttle in 1994. Modifications to the SIR-C radars included a 60 m retractable boom equipped with C-band and X-band receive only antennas attached to the boom's end. Additional metrology systems designed to measure the shuttle position and attitude as well as the position of the boom antennas to high accuracy was also added. To map the world in the 10 days allotted for the mission required the C-band radar to operate in ScanSAR mode. The C-band interferometry data was collected in swaths comprised of four subswaths each as shown in Figure 1. ScanSAR mapping modes alternately switch between two (or more) beam positions in the cross track direction to increase the swath width at the expense of along track resolution. Exploiting the C-band polarization capability, the SRTM C-band radar operated in ScanSAR mode on vertical (V) and horizontal (H) polarizations to achieve an effective swath width of 225 km while maximizing the SNR over the swath.

Operational processing of the C-band ScanSAR interferometric data into a seamless topographic map required several processor innovations. In this paper we present an overview of the SRTM processor and show an example of SRTM processed data.

SYSTEM OVERVIEW

Constructing accurate height maps using radar interferometry requires precise knowledge of the platform position, attitude, and interferometric baseline as well as knowledge of the radar operating parameters [2]. Table I provides a list of the major system parameters. To meet these stringent requirements, the SRTM mapping instrument was equipped with a specially designed motion measurement system. Absolute position information was

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Table I SRTM System Parameters

Parameter	Value
Baseline Length	62 m
Baseline Orientation Angle	45°
Wavelength	.0566 m
Burst Length	60 - 100 pulses
Platform Altitude	240 km
Platform Velocity	7.5 km/s
Look Angle Range	30° - 60°
Antenna Lengths	12 m/8 m
PRF Range	1330 - 1550 Hz

determined from two GPS receivers located on the outboard antenna. Attitude information was derived from a combination of star tracker and IRU measurements. The interferometric baseline (vector between the inboard and outboard antennas) was measured using a combination of an optical target tracker, which measured the angles to several targets located on the outboard antenna structure; and an electronic ranging device used to measure the distance between inboard and outboard antennas. The motion measurement system is part of the Attitude and Orbit Determination Avionics (AODA) system that reduced all the motion measurements and provided that information in the AODA PADR file. The PADR file includes the correspondence between the radar clock (MET) and GPS time. This file provides the SRTM Processor with the precise timing information required to align the pulse data with the associated motion and baseline data

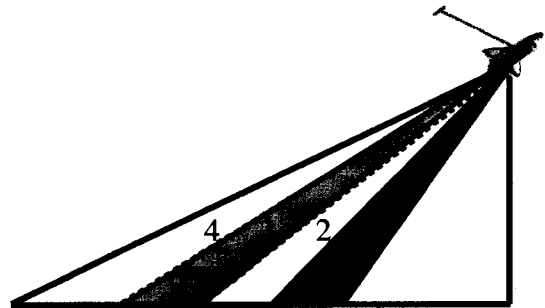


Figure 1. The SRTM C-band radar collects data in two subswaths simultaneously using horizontal (H) and vertical polarization (V). The four ScanSAR subswaths are numbered 1-4 starting from nadir as shown above.

PROCESSOR DESCRIPTION

The Topographic Processing Subsystem (TPS) is comprised of two major programs, the Preprocessor and the Processor. The Preprocessor's main function is to use inputs from AODA, the Verification and Calibration Subsystem and C-band radar command parameters to generate a Processor command file and time varying parameter file, that includes motion measurement information, in an appropriate coordinate system and format for the Processor. The Processor's main function is to generate strip maps from the raw radar signal history using a modified version of the algorithm described in [3]. TPS processes each subswath separately to produce a geocoded strip map height file.

Data collected in burst mode must be processed slightly differently than the standard strip mode SAR data in order to reduce the amount of phase distortion to the interferogram. Image data is processed burst by burst for the inboard and outboard antennas and an interferogram is formed for each burst. Data from multiple bursts, called a patch (30-50 bursts), are combined to form one large interferogram prior to filtering and unwrapping. An overview of the major processing function in the processor

Range Compression

In the range compression module raw signal data is decoded from 4-bit BFPQ format to floating point. This is done via a look up table in both cases. Range compression is done using the standard Fourier transform convolution algorithm. A calibration tone was injected into the returned echo data to track phase drift between the inboard and outboard channels that is extracted and stored for use in computing the relative phase between the two interferometric channels. A phase ramp is applied to the reference function of the two channels to remove differential channel delay and correct for an overall phase constant.

Motion Compensation

Motion compensation is the process where the radar signal data are resampled from the actual path of the antenna to an idealized path called the reference path. Motion compensation is done to common reference path which insures the data are co-registered in range after image formation, applies the appropriate range spectral shift for a flat surface and flattens the fringes.

Presumming and Azimuth Compression

A number of algorithms can be used for SAR image formation. For SRTM we need an algorithm that can be used with burst mode data and can process the large

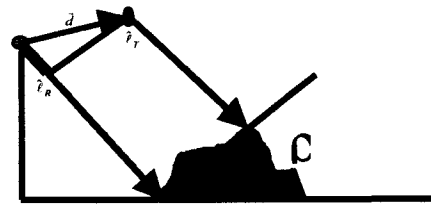


Figure 2. A range and phase correction equal to the range difference between the actual and desired path is applied to both channels is shown highlighted in blue.

volume of data efficiently. In addition either through presumming or as part of the azimuth compression process a 7 m along track shift between inboard and outboard antennas must be removed to have them co-registered in azimuth after image formation. Two algorithms are implemented in the processor. The algorithm to be used for production that incorporates the presum operation is the modified SPECAN algorithm described in [4].

Interferogram Formation and Filtering

As described previously interferograms are generated for each burst a combined in to a larger patch interferogram. The interferogram is filtered to reduce noise using either a boxcar lowpass filter or power spectral filtering as described in [5].

Unwrapping and Absolute Phase Determination

Unwrapping uses an updated version of the residue based unwrapping algorithm first described in [6]. The algorithm has been improved to be more robust and maximize the unwrappable area. Absolute phase is determined by averaging the unwrapped phase to 500 m postings and adding multiples of 2π and then comparing the associated height values to a low resolution DEM. The multiple with the smallest RMS residual is selected.

Height Reconstruction and Regridding

Interferometric height reconstruction is the determination of a target's position vector from known platform ephemeris information, baseline information and interferometric phase. Prior to height reconstruction the interferometric phase altered during the motion compensation process is "restored" to the true phase as sensed by the antenna at the time the point was imaged called inverse motion compensation. Correction for dry tropospheric effects on all of the interferometric measurements (range, Doppler and interferometric phase) is made prior height reconstruction. Certain affects such as multi-path or switch leakage can result in systematic phase distortions that can affect the reconstructed height in 1-10 m range. Provided the multi-path or switch leakage signal resulting in the phase distortions is stable then it can

be removed through the use of a phase screen. The phase screen applies a range dependent correction that to the interferometric.

After height reconstruction each unwrapped phase point consists of a triple of numbers, the SCH coordinates of that point. This point does not necessarily lie on an output grid point. Regridding is a resampling of the SCH triples to a uniform grid. Four regridding algorithms included in the processor are nearest neighbor, simplicial, convolutional and surface fitting. Convolutional and surface fitting regridding algorithms also incorporate an adaptive regridding process that adjusts the amount of smoothing depending on the amount of topographic relief compared to the intrinsic measurement noise.

PROCESSING RESULTS

Using a data collected from a datatake on day four of the mission we processed a strip of data that extended from 100 km north of San Francisco to just south of the tip of Baja, California. This data take contains one of our corner reflector calibration arrays deployed in the Mojave desert just east of Los Angeles. Figure 4 a section of subswath 1 processed with the TPS processor containing the Los Angeles metropolitan area. The DEM is posted at 30 m, the standard posting for SRTM high-resolution products.



Figure 4. A fully processed strip map of Los Angeles collected on day four of the mission. Brightness is proportional to the radar backscatter and color elevation contours are overlaid with 250 m between contours having the same color. LAX is the airport seen in the middle of the image.

CONCLUSIONS

The SRTM Topographic Processor is designed to automatically generate topographic maps using the ScanSAR C-band data collected during the SRTM mission. By incorporating several new processing algorithms and giving the user access to a wide variety of processing options make the processor suitable for robustly processing the variety of terrain types found in a global data set. Results of processing data to date indicate the processor is working as intended and will generate the first globally consistent digital elevation map of the world.

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